Chromosphere above the Sunspot Umbra as seen in NST and IRIS

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Umbral Spikes and Flashes

Tian et al. 2014; TESS Poster 203.11 by Strauss, Fleck & Andretta; Kleint et al. 2014; Rouppe van der Voort & de la Cruz Rodriguez (2013); Yurchyshyn et al. 2014

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IRIS Umbral Shocks

The amplitude and frequency of shocks are irregular

Mg ii k spectra at $t = 3000-3100\,\text{s}$ show an “abnormal” shock pattern, i.e., a sequence of six short duration ($\approx 70\,\text{s}$), low amplitude shocks, while the Si iv (TR) display the regular amplitude, long duration shocks.

The pattern is reversed at $t = 3800 - 4200\,\text{s}$, when the Si iv line shows almost no shock activity in the TR, while the chromosphere was beating with its regular rhythm.
**IRIS Shock Time Profiles**

Fig. 2.— Mg II $k$ (red) and Si IV (black) blue wing intensity time profiles measured 0.05Å off the line center along the black dotted line for area C (center of the umbra). Time counting starts at the beginning of the IRIS observing run.

- Average delay $t = -15$ s Si iv shocks (black curve) delayed relative to Mgii k line; (Tian et al. 2014, see Madsen et al. 2014)
- The delay varies: between 2400 -2800 s it is 40 s, and $t=0$ at $t = 4200–4500$ s. There are intervals with no reasonable correlation ($t = 1200–1800$ s).
- These oscillation patterns suggest that a complex interaction may exist between the upward travelling waves and those reflected from the TR and/or corona back to the photosphere.
There is large-scale pattern in variations of the shock intensity across a sunspot as well as with height above the sunspot. Shackhs appear to be more intense above light bridges. At the same time, there are locations inside the umbra where TR shocks cannot be detected and we speculate that the magnetic field configuration may be responsible for shock production and wave propagation above a sunspot.
Umbral Flashes

Green lines indicate locations of umbral flashes as detected in consecutive 80 NST offband H-alpha images.

All detected flashes repeatedly appeared at the same locations and had ribbon-like shape.

They formed on that side of the light bridges that faced the center of the sunspot.
Umbral Flashes: Fine Structure

Dynamics of UFAs as seen in NST Halpha+0.4A (top) and Halpha-0.4A (bottom). L1 and R1 mark locations of two bright UF lanes. The short line segments mark the edge of an expanding UF lane, while the arrow shows the direction of expansion. The large tick marks in the leftmost top panel indicate 1 Mm intervals.
Why the Light Bridges?

Tian et al. 2014 pointed out the connection between the footpoints of coronal loops and the bright TR umbra. We emphasize a possible connection between the bright magnetoconvection features (LBs, clusters of UDs) and bright UV umbra and coronal loop footpoints.

Hollweg et al. (1982): shock formation depends on the vertical gradient of Alfven speed. If $V_A$, decreases with height then shocks form more effectively. Such conditions are met either in rapidly expanding vertical flux tubes and/or near edges of flux tubes, where fields may become mostly horizontal.

In sunspot umbra, such conditions exist near LBs and UD clusters, which are considered field-free structures. In this case adjacent umbral fields expand into the atmosphere above these features thus creating a narrow lane of negative vertical gradient of if $V_A$ with favorable conditions for formation of chromospheric shocks.
Photosph. Dynamics in LBs

Lagg et al. 2014; Louis et al. 2014; Bharti 2015

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Evolution of Stokes Parameters